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Exogeneity tests for the Chinese and U.S. external balance: Empirical evidence of the connection and the subprime crisis

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Abstract

This paper studies the global imbalances that occurred in the first years of the twenty-first century. The analysis encompasses the two biggest countries in the world: the U.S.A. and China. Many authors defend the assertion that the relationship between the current accounts of these two countries was one important cause of the subprime crisis. While the U.S.A. has increased its deficit in the last decade, China has improved its surplus. To investigate this relationship, this study performed exogeneity tests. Moreover, it conducted Granger causality tests following the approach of Toda–Yamamoto (1995). The results showed that there is a real causal relationship between the American and the Chinese external balance. Furthermore, the global imbalance between these two countries contributed to the subprime crisis, because the tests detected structural breaks for the external balances of America and China in 2008. The dynamics of the Chinese external balance changed after the subprime crisis.

JEL classification: F40; F32; E20

Keywords: Exogeneity test; External balance; Macroeconomic imbalance

Resumo

Este trabalho estudou a dinâmica da relação entre o saldo externo chinês e o saldo externo norte-americano nos primeiro anos do século XXI. O estudo desta dinâmica se justifica uma vez que a mesma é apontada por muitos autores como uma das causas da crise *subprime*, ocorrida em 2008. Com a finalidade de estudar esta dinâmica foram usados os testes de exogeneidade para investigar a existência da relação entre o saldo externo destes dois países. A investigação desta relação foi dada por meio da abordagem de Toda–Yamamoto (1995). A conclusão que este trabalho chegou foi que o desequilíbrio macroeconômico entre China e EUA tem uma relação causal. Além disso, estes desequilíbrios estão relacionados com a crise de 2008, uma vez que foram detectadas quebras

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estruturais para o saldo externo dos dois países no ano de 2008 e a dinâmica do saldo em transações correntes do saldo externo chinês se modificou após a crise *subprime*.

Palavras chave: Testes de Exogeneidade; Saldo externo; Desequilíbrio macroeconômico

1. Introduction

The early years of this century were marked by structural changes in the world economy. In this period, the attention turned to the group of developing countries that was standing out with growth rates above those of the rest the planet. In this context, China became the fourth-largest economy in the world in 2006, the third-largest in 2007 and the second-largest in 2010.

During these years, the world experienced a strong increase in the macroeconomic imbalance, which, according to Feldstein (2011), was characterized by a sharp increase in the current account balance in some countries. The United States and China were highlighted by the increase in the current account balance because of their size and the commercial and financial relations that these countries had with the rest of the world. While the U.S. was incurring increasing deficits in its current account balance, China was achieving an increasing surplus.

The growth in the external balance of some countries, especially China, generated strong market liquidity that allowed the maintenance of a low interest rate throughout the world during the first half of the 2000s. Further, for Catte et al. (2011), this expansionary monetary policy was crucial to the emergence of the current account deficit in the U.S. economy and consequently in the housing market bubble. With the bankruptcy of Lehman Brothers in September 2008, there was strong turbulence in the worldwide economy. The bankruptcy was the most serious event in the international economy, related to financial institutions that operated in low-quality mortgages (subprime), mainly in the United States, since 1930. These events culminated in a severe economic crisis, which, according to Reinhart and Rogoff (2009), was the "Second Great Contraction," in analogy to the "Great Depression" of the past century.

Several arguments have tried to explain the main cause of this crisis. Some works, like those by Bresser-Pereira (2009), Cardim (2008) and Paula and Ferrari (2010), have emphasized the deficiency of the regulatory framework as the main cause of the financial economic crisis. Other studies, such as those by Caballero and Krishnamurthy (2009), Chinn et al. (2011) and Lane and Milesi-Ferreti (2011), have suggested that the increased macroeconomic imbalance was a major factor in the outbreak of the crisis.

The argumentation of macroeconomic imbalance is based on events that occurred mainly in the last ten years, when China stood as a big player in international trade, after its entry into the WTO. While the U.S. spent this decade financing its overspending based on two wars, China at the same time was financing the deficit of several countries from its policy of encouraging exports.

After the attack on the Twin Towers in 2001, the U.S. used an expansionary monetary policy to mitigate the effects of insecurity caused by the assault. The U.S. had no trouble financing its current account deficit because of the aggressive Chinese commercial policy. China had been investing most of its reserves in the North American market. On the other hand, the U.S. had no concern about inflation since China had become an export power at a lower price. Since the U.S. faced no problems either in financing its deficit or controlling inflation, the FED maintained an extremely expansionary monetary policy until 2005–2006, when inflation began to rise and the monetary authority began to raise the interest rates.

This period of expansionary monetary policy, boosted by the excess external imbalance invested by countries like China in the U.S. market, led to a housing boom, combined with excessive leverage in the financial sector. This sector began lending with no credibility. Since the interest rates on mortgages were postfixes, the increases in the interest rate were a strong cause of defaults, which were one of the matters of the 2008 crisis.

Despite the crisis having been characterized as being a result of high-risk loans, one of the possible causes of this higher risk that banks assumed could be the long period characterized by a monetary policy of low interest rates and high liquidity, which in turn was made possible by the Chinese surpluses. Although the dynamics of the Chinese current account surpluses and the U.S. deficit cannot be directly considered as causes of the mortgage crisis, in the

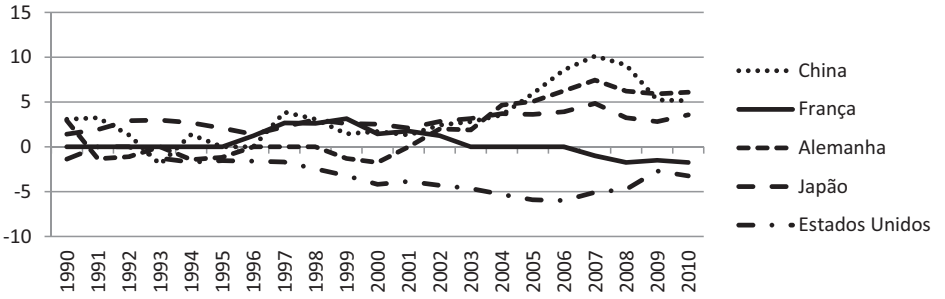

Chart 1. Balance on current transactions of the G5 between 1990 and 2010 (percentage of GDP).
Source: Chart prepared by the authors using data from the IMF.

absence of such dynamics, the American domestic inflation would not have remained at low levels for such a long time.

Thus, examining the dynamics of the relationship between the current accounts of the two countries becomes relevant to assist in understanding the macroeconomic events that marked the subprime mortgage crisis. In this case, an issue to investigate is whether the successive Chinese current account surpluses explaining the U.S. current account deficits is relevant, as China has adopted a deliberate policy of growth based on exports and investment of its financial surplus from these trade surpluses in U.S. markets. Therefore, the discussion presented above suggests that the Chinese business strategy represented an important factor in sustaining the deficits of the U.S. In terms of the specification of the econometric model used to investigate this question, it does not seem reasonable to assume that we can ignore the possible effects of the U.S. deficits on the Chinese current account.

This article aims to contribute to improving the understanding of this issue from the specification of a macroeconomic model of the dynamics of the U.S. and China. We also use concepts of exogeneity as proposed by Engle et al. (1983), and causality as proposed by Granger (1969), in such a way as to investigate the possible bidirectional effects. The assumption is that if there is endogeneity, not only does the imbalance in the Chinese current account surplus precede the dynamics of the U.S. current account temporally, or in other words, causes in the Granger sense, but also the Chinese current account cannot be analyzed outside the system that includes the variables used to model the dynamics of the U.S. current account.

If the Chinese current account is exogenous, we can condition the U.S. current account to the observation of an exogenous variable indicating that the Chinese current account imbalance does not have a dynamic effect on the U.S. current account. In this last case, the argument that the macroeconomic imbalances provided a favorable environment for the crisis loses strength to the extent that there is no relationship between the endogeneity of the imbalance in the current accounts of these countries, and in this case other factors would possibly be most prevalent (Aizenman and Jinjarak, 2009; Corden, 2009; Mackinnon and Schnabl, 2009).

This paper seeks empirical evidence in terms of the dynamics of the current accounts of both countries to support the hypothesis that successive Chinese current account surpluses explain the U.S. current account deficits without intending to present an econometric model to produce forecasts or analyses of the economic policy in relation to the current accounts of both countries.

Following this introduction, the second section of the paper presents a brief demonstration of the evolution of data that suggest a link between the external balances of these two countries. The third section provides a literature review of the empirical studies on macroeconomic imbalances. The fourth section contains the methodology and data. The fifth section presents the econometric results and the sixth the conclusions.

2. Motivation

China and the U.S. were not the only countries that had macroeconomic imbalances in the last decade, as highlighted by Mackinnon and Schnabl (2009), but these two countries are the ones that stood out because of their importance and because of the strong increase in the variation of the current account balances, which has intensified severely in recent years. Chart 1 shows the current account balance of the G5 (the United States, China, Japan, Germany and France).

Table 1
Current account balance of the U.S. and China (millions of dollars), from 1990 to 2010.

Year/Country	China	U.S.	China/U.S.
1990	11.997	−78.965	−15%
1991	13.271	2.895	–
1992	6.402	−51.614	−12%
1993	−11.902	−84.816	–
1994	7.657	−121.612	−6%
1995	1.618	−113.571	−1%
1996	7.243	−124.773	−6%
1997	36.962	−140.720	−26%
1998	31.472	−215.066	−15%
1999	15.669	−301.653	−5%
2000	20.519	−416.342	−5%
2001	17.405	−396.596	−4%
2002	35.422	−457.245	−8%
2003	45.875	−519.097	−9%
2004	68.659	−628.521	−11%
2005	134.100	−745.773	−18%
2006	232.800	−800.621	−29%
2007	353.900	−710.304	−50%
2008	412.400	−677.134	−61%
2009	261.000	−376.551	−69%
2010	305.300	−470.898	−65%

Source: Table prepared by the authors using data from the IMF.

Those countries represented 50% of the world economy in 2007. From Chart 1, we can see that three countries (China, the U.S.A. and Germany) stood out because they had significant increases in their current account balances.

For Hallett and Oliva (2011) the literature suggests that the current account balance must not exceed 4 to 5% of the GDP. However, when we analyze Chart 1, it shows that with the exception of Germany, only the U.S. and China have a current account balance greater than 5% of their GDP, from 2004 to 2007 in the first case and from 2005 to 2011 in the second case. China moved from a surplus of just 1% of its GDP in 2001 to over 10% of its GDP in 2007, the year before the collapse of Lehman Brothers. The American deficit moved from 3.8% of its GDP in 2001 to almost 6% in 2006, the year of the beginning of the problems in the housing market. As we can see, after the crisis, there was a decrease in the macroeconomic imbalance.

Analyzing the Chinese and the American current account in Table 1, it is apparent that the increase in imbalances started in 2001.

Table 1 shows that the Chinese surplus rose by more than 1900% between 2001 and 2007, as the North American deficit increased by more than 100% over the same period. In values, the Chinese surplus increased by $336 billion, while the U.S. deficit increased in the same period by $313 billion. Since the rate of increase of the Chinese balance was greater than that of the American balance, the proportion of the Chinese surplus with respect to the U.S. deficit increased from 4% in 2001 to 61% in the crisis year (2008). Since the sums of the outstanding balances of the current accounts of countries around the world have to be zero, it is possible that the Chinese surplus is related to the U.S. deficit. Another finding that suggests a causal relationship between the external sector of China and that of the U.S. is the analysis of the annual accumulation of Chinese reserves, which would bring the result not only of the current account balance, but of the balance of the capital account. This finding makes sense, since China maintains a controlled exchange rate using interventions in the foreign exchange market to allow its currency to be strongly devalued, as evidenced by Catte et al. (2011), Cheung et al. (2009), Corden (2009) and Mackinnon and Schnabl (2009).

In Table 2, we can see that starting in 2001, the proportion between China's reserve and America's deficit became significant. In 2000, a year before China joined the WTO, the variation in its foreign exchange reserves amounted to 3% of the U.S. deficit; in 2004, the variation corresponded to 33% of the U.S. deficit. The evolution between the Chinese reserves' accumulation and the U.S. deficit increased throughout almost the entire decade following the entry of China into the WTO, becoming 125% of the U.S. deficit in 2009.

Table 2
Current account balance of the U.S. and annual accumulation of China's currency reserves (in millions of dollars) and the ratio between them, from 1990 to 2010.

Year/Country	U.S.	China's Reserve	China's Reserve/U.S.
1990	−78,965	11,662	−15%
1991	2895	14,099	–
1992	−51,614	−23,077	–
1993	−84,816	1768	−2%
1994	−121,612	30,560	−25%
1995	−113,571	22,476	−20%
1996	−124,773	31,639	−25%
1997	−140,720	35,687	−25%
1998	−215,066	6448	−3%
1999	−301,653	8524	−3%
2000	−416,342	10,519	−3%
2001	−396,596	49,842	−13%
2002	−457,245	76,503	−17%
2003	−519,097	117,022	−23%
2004	−628,521	206,348	−33%
2005	−745,773	207,014	−28%
2006	−800,621	246,979	−31%
2007	−710,304	467,788	−66%
2008	−677,134	418,987	−62%
2009	−376,551	472,524	−125%
2010	−470,898	450,035	−96%

Source: Table prepared by the authors using data from the IMF.

3. Literature review

3.1. Macroeconomic imbalances between the U.S. and China

After the beginning of the subprime crisis, the debate on the macroeconomic imbalance converged in a conciliatory position in which the imbalances in the current account balance should have been corrected before the crisis. The strong and persistent imbalances in the current account balance were seen as an indicator of instability in the functioning of the global financial system (Hallett and Oliva, 2011).

According to Caballero and Krishnamurthy (2009, p. 2), despite the crisis having materialized with the housing bubble, it was caused by the demand of some countries, such as China, for safe assets like bonds of the U.S. debt, financing its deficit easily. For Caballero and Krishnamurthy apud. Caballero (2010, p. 2), that demand for safe assets put strong pressure on the U.S. financial system and its incentives. Then, the U.S. financial system began to create financial instruments that allowed the securitization of debt.

According to Aizenman and Jinjarak (2009, p. 1), the literature on macroeconomic imbalances refers to the enigma of the poor financing the rich, for example the case of China and the U.S. Regarding the growth of the U.S. deficit, Blanchard et al. (2005) suggested that the large current account deficit of the U.S. is partly explained by the strong increase in the demand for U.S. government bonds. According to Feldstein (2011, p. 1), it was not only the U.S. and China that had current account imbalances, but the subprime crisis has shown that the macroeconomic imbalance of China and the U.S., which has worsened since 2005, is not sustainable. Mackinnon and Schnabl (2009) suggested that the link between the current account deficit of the U.S. and the Chinese surplus is the sharp increase in the current account balance that China experienced from the year 2000. Furthermore, according to the authors, the Chinese current account balance reached $359 billion in 2007, equivalent to 10% of the Chinese GDP. This surplus would be related to the strong increase in the U.S. deficit in the current account, which reached $750 billion in 2007, equivalent to 6.1% of the U.S. domestic product.

Several reasons may explain the growth of the macroeconomic imbalance between China and the U.S. According to Resende (2009, p. 5), the Chinese surpluses were based on the repression of its internal demand through an economic

policy that prioritized foreign trade. Corden (2009) suggested that China's currency undervaluation is an important factor in explaining the increase in the Chinese current account balance in recent years.

For Caballero and Krishnamurthy (2009), conventional wisdom states that the concentration of risks and bubbles is the result of errors in the regulatory policies. However, this knowledge omits two key factors that caused the bubble in the U.S. mortgages, which relate the increase in the Chinese current account surpluses to the deficits of other countries, such as the U.S. In the words of the authors:

> First, the U.S. experienced in the last decade a large flow of capital from foreign investors seeking assets that retain value. Second, especially after the technology bubble (Nasdaq), excess of foreign savings flowed especially for safety investments. This should not be surprising because a large amount of capital that entered in the U.S. came from foreign Central Banks. (Caballero and Krishnamurthy, 2009, p. 3)

The large flow of capital in the world contributed to excess liquidity in the international market, allowing strong misalignment in the current account balances of the U.S. and China and permitting the Americans to keep low interest rates. Before the subprime crisis, the low interest rates contributed to investors seeking greater risk. These low interest rates also contributed to the strong increase in the price of real estate in the U.S. until the bubble burst.

3.2. *Empirical work on macroeconomic imbalances*

Chinn et al. (2011, p. 9) analyzed the external balance of 109 countries, of which 23 are industrialized and 86 are developing countries, in the period from 1970 to 2007. The authors developed a model following the panel methodology in which the dependent variable is divided into three: balance on current transactions, investment and domestic savings. Regarding the independent variables, they used a vector of macroeconomic indicators, in addition to government savings and a measure of financial development. The authors found that the twin deficits hypothesis is consistent, so a government budget deficit is closely connected with a negative balance of current transactions; a country with a positive net position of assets tends to have a positive external balance, as is the case in China; oil exporters have a large positive balance of foreign savings; and rich countries have a current account deficit, as is the case of the U.S.

Cheung et al. (2009) studied the strong increase in Chinese foreign trade surplus, shaping the multilateral trade of China using the time series methodology. The authors reported that the difficulty of working with Chinese data may be responsible for some unexpected results. First, they found that an increase in China's income expands its exports and a depreciation of the exchange rate decreases Chinese exports.

When the authors modeled the bilateral trade between the U.S. and China, they found that China's exports are sensitive to the value of the dollar. Appreciation of the dollar against the yuan increases the Chinese exports to the U.S., while Chinese imports are sensitive to the domestic income. This result indicates that China's policy of devaluing the exchange rate was an important factor in the increase in its surplus.

For Lane and Milesi-Ferreti (2011), the strong shock to the current account balance of many nations in crisis has shown how the macroeconomic imbalance was unstable in the pre-crisis period. The authors estimated an excess macroeconomic imbalance in the period between 1969 and 2008 for 65 countries. Thus, they found a strong relationship between government savings and current account balances. They also showed that an increase in the relative income between any country and its major trading partners causes an improvement in the external balance of the country.

Meanwhile, Aizenman and Jinjarak (2009) estimated a model following the panel methodology for 69 countries, in which the main difference with respect to the main models on current transactions presented above was to add the external balance of the U.S. to explain the external balance of other countries. The authors analyzed the period between 1981 and 2006. They found that the current account deficit of the U.S. is positively linked with the current account balance of the countries analyzed. When the authors analyzed China, they showed that the most important component in explaining the Chinese external surplus is the American deficit, indicating that there is a relationship between the foreign balances of the two countries.

Since the relationship between the external balance of the U.S. and that of China is recent, we did not find empirical literature that relates this relationship in the modeling of time series analysis for the period of this article. We found

empirical models about this relationship using the panel methodology, but we could not use panels because there are many variables that are not available for China.

4. Methodology

4.1. Econometric model

Since there is no available model to estimate the bilateral relationship discussed above, we constructed the model of this work by looking for variables that are used in panel models and are available for both countries.

First, we performed unit root tests to check the stationarity of the variables. In the second step, we performed an econometric exercise, in which tests were used to detect the possible existence of exogeneity between the current account balance of the U.S. and that of China. According to Hendry (1995), there are three types of exogeneity: weak exogeneity, strong exogeneity and superexogeneity.

Sachsida and Mendonça (2006) used the three types of exogeneity to identify the dynamic model associated with investment and savings. According to Sachsida and Mendonça (2006), weak exogeneity is necessary to infer the parameters of the model. In the presence of strong exogeneity, the model may be used to make forecasts. Ultimately, superexogeneity safeguards the model from Lucas criticism.

The methodology we used for the weak exogeneity test is based on Engle et al. (1983). In the first step, we used a regression called a conditional equation (or a conditional model), with the dependent variable as a function of all the supposedly exogenous variables, as in Eq. (1), where Y is the dependent variable, X is the vector of independent variables and η is the residue.

$$Y = X\beta + \eta \tag{1}$$

In the second step, we ran a regression called a marginal equation (or a marginal model), containing the variable that we believed to be exogenous against the lags, as in Eq. (2), where X is the dependent variable (presumably endogenous), X_{t-i} are the lags as independent variables and σ is the residue.

$$X = X_{t-i\rho} + \sigma \tag{2}$$

The third step of the test consists of examining the correlation between the residues of the conditional equation and the residues of the marginal equation, as expressed in Eq. (3).

$$\hat{\eta} = c + \delta\hat{\sigma}. \tag{3}$$

If δ is significant, it means that the variable in question is endogenous. If δ is not significant, the variable is weakly exogenous. To be strongly exogenous, a variable must have two characteristics: weak exogeneity and no causality in the Granger sense. The test for the first characteristic has been shown. For the second characteristic, it is important to note that according to Araujo and Dias (2006), the Granger causality test does not determine whether a variable is exogenous or not; it just determines the temporal precedence of one variable over another.

For the test of causality in the Granger sense, we followed the Toda–Yamamoto procedure. According to Toda and Yamamoto (1995), the conventional asymptotic theory is not valid when using a VAR in levels and when the variables are integrated or cointegrated. Trying to correct this problem, the authors developed a new method, which, according to Tomazzia and Meurer (2009), shows that the properties remain statistically robust for a VAR in levels with the order of integration and cointegration unknown.

Furthermore, according to Zapata and Rambaldi (1997), the Toda–Yamamoto procedure is simple to run and Monte Carlo experiments have shown that this procedure provides a similar performance when considering 50 observations. The Toda–Yamamoto procedure for non-Granger causality consists of a Wald test, which examines the model constraints. Initially, we defined the optimal number of lags of the VAR d and the maximum order of system integration t. Subsequently, we estimated the VAR in levels with a total of $(d+t)$ lags and ran the Wald test of restriction with d initial weightings. The parameter test for a VAR (d) followed the Chi-squared distribution.

Regarding superexogeneity, there are two characteristics that a variable must have to be considered superexogeneous: weak exogeneity and structural invariance. Sachsida (1999) suggested two tests to examine the superexogeneity. The first test indicated by the author is a graphical comparison between the marginal residues of the marginal model

Table 3
Correlation matrix of the variables used in the model.

	BBC	BBE	BC	EE	EC	YE	YC	SG
BBC	1	−0.519838	0.778103	0.305373	−0.67816	−0.49227	0.510006	−0.4186
BBE	−0.51983	1	−0.741763	0.410574	0.480174	−0.07028	−0.85007	0.07380
BC	0.778103	−0.741763	1	0.212291	−0.86054	−0.25609	0.682760	−614,604
EE	0.305373	0.410574	0.212291	1	−0.31408	−0.54265	−0.41086	−0.6179
EC	−0.67816	0.480174	−0.860543	−0.31408	1	0.182190	−0.40825	0.67566
YE	−0.49227	−0.070282	−0.256094	−0.54265	0.182190	1	0.141883	0.52310
YC	0.510006	−0.850072	0.682760	−0.41086	−0.40825	0.141883	1	−0.0610
SG	−0.41861	0.073802	−614,604	−0.61790	0.675667	0.523109	−0.06100	1

Source: Table prepared by the authors using data from the article.

(Eq. (2)) and those of the conditional model (Eq. (1)). If there is no coincidence of breaks in the series, we accept superexogeneity.

In the second test suggested by the author, the marginal model (Eq. (2)) is estimated and the residues saved. The second step is to add the residues in squared, with their lags, as the independent variable in the conditional model (Eq. (1)). In addition, according to the author, the important part of the test is the Wald test, with which we check the significance of the residues squared together.

4.2. Data

The functional form established for the analysis of the Granger causality tests and exogeneity between the external balance of the U.S. and that of China is proposed in Eqs. (4) and (5).

$$BBE = f(BBc, BC, YE, YC, EC, EE, SG) \tag{4}$$

$$BBC = f(BBE, BC, YC, YE, EE, EC, SG) \tag{5}$$

BBC and *BBE* are defined as the current account balance of China and the U.S., respectively. We used the balance of goods as a *proxy* for the current account balance, since these data were not found in the databases in the case of China. We also used this proxy because there is a high correlation between the current account balance and the balance of goods. In the case of China, the correlation rate is 0.99, and in the case of the U.S., the correlation rate is 0.87. *BC* is the flow of world trade and *YE* and *YC* are the internal income of the U.S. and China, respectively. SG is the U.S. government savings (the U.S. government deficit by the nominal concept) and *EE* and *EC* are the real effective exchange rate of the U.S. and China, respectively.

The quarterly data encompass the period between the first quarter of 1999 and the last quarter of 2011, totaling 52 observations. The variables, with their respective sources, their definition and their possible relationships, are described in Chart 2. Table 3 shows the correlation matrix between the variables.

We can see in Table 3 that there is a negative correlation between the balance of goods of the U.S. (BBE) and that of China (BBC). This fact was expected since the data already presented showed this possible correlation. With respect to the variable BBC, it has a high positive correlation with the level of world trade (BC) and a negative correlation with the Chinese exchange rate. This fact is due to China being one of the greatest players in world trade and when the world trade grows, China also grows.

Regarding the Chinese exchange rate (EC), we had expected that the more undervalued the Chinese currency was, the higher its balance of goods would be. However, the correlation between EC and BBC was negative. One possible explanation is that the nominal exchange rate in China is tightly controlled by the monetary authority, so it is hard to measure their relationship. Another explanation could be the short-term effects of changes in exchange rates on the trade balance, called the J-curve. BBC has a positive correlation with the Chinese domestic income (YC).

As the literature suggests, there is a negative correlation between BBC and YE. This implies that China is a country that is growing toward the foreign market, so when the Chinese trade balance increases, its domestic income also grows. The negative correlation with the American internal income shows that the increase in China's external balance

Variable	Description	Link	Measure	Source
BC	Flow of world trade (sum of exports and imports)	We expect a positive sign between the flow of trade and the current account balance of the selected countries.	US$ billions+	IPEADATA
BBE	Net trade in goods between the U.S. and the world	We expect an inverse relationship between BBE and BBC as suggested by the data.	US$ billions+	OECD**
BBC	Net trade in goods between China and the world	We expect an inverse relationship between BBE and BBC as suggested by the data.	US$ billions+	OECD**
YE	American domestic income (change in real GDP in a quarter from the same quarter of the previous year)	We expect a negative link between the growth of the domestic product and the external balance.	%	IMF* e BSC****
YC	Chinese domestic income (change in real GDP in a quarter from the same quarter of the previous year)	We expect a negative link between the growth of the domestic product and the external balance.	%	IMF* e BSC****
EE	Real effective exchange rate (real exchange rate weighted by the major American trading partners)	A devaluation of the real exchange rate can worsen the external balance in the short term because of the J-curve effect and improve this balance in the long term if held to the Marshall–Lerner condition.	Index 2005=100	IMF*
EC	Real effective exchange rate (real exchange rate weighted by the major Chinese trading partners)	A devaluation of the real exchange rate can worsen the external balance in the short term because of the J-curve effect and improve this balance in the long term if held to the Marshall–Lerner condition.	Index 2005=100	IMF*
SG	American public deficit	We expect that the American nominal deficit has a negative effect on the current account balance of the U.S. and a positive effect on the Chinese current account balance.	US$ billions+	BEU***

Chart 2. Description of the variables used in the econometric model.
* International Monetary Fund, ** Organization for Economic Co-operation and Development, *** Bureau of Economic Analysis, **** Bureau of Statistics China + Constant prices of 2001.
Source: Chart prepared by the authors using data from the article.

means that the U.S. grows less, as imports grow faster than exports. Concerning the nominal deficit of the U.S., the smaller it is, the smaller the external surplus of Chinese savings will also be. BBE has a high negative correlation with the level of world trade (BC) and the Chinese domestic income (YC). Since the U.S. is responsible for much of the global demand for goods and also because Americans traditionally face external deficits, increases in world trade mean greater demand for goods from the U.S. economy, resulting in a higher trade deficit. In addition, since China is growing toward the international market, China's higher growth means higher external U.S. deficits. According to Table 3, the U.S. external balance is positively correlated with the exchange rate of the U.S.; this fact implies that devaluations have no positive impact on the U.S. external balance.

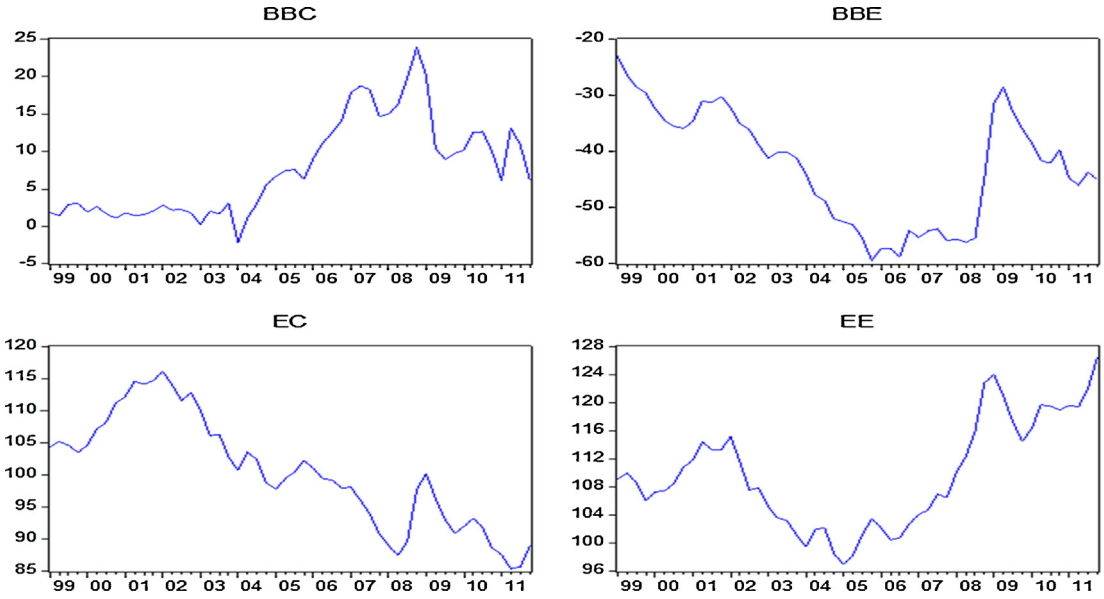

Chart 3. Evolution of the variables BBC, BBE, EC and EE in the period 1999–2011.
Source: Chart prepared by the authors using data from the article.

5. Econometric results

5.1. Unit root test

We used unit root tests (ADF, DF-GLS, Philips–Perron, KPSS, ERS)[1] to verify the integration of the variables in the model. Furthermore, we used the Ng and Perron (2001) unit root test with the OLS method (OLS detrend) and modified Akaike criterion as described by Perron and Qu (2007), because according to Divino et al. (2009), the Ng–Perron unit root test generates gains in power and size comparable with tests like the ADF and PP tests.

Initially, we ran all these unit root tests in levels. The result showed that the variables were not stationary in level I(0) at the 5% level of significance in all the unit root tests. The only three exceptions were the variable BC, which was I(0) in the ERS test, and YE, which was also I(0) in the ADF test and the ERS test.

One probable reason why the tests did not reject the null hypothesis that there are unit roots may be structural breaks that are present in almost all the variables. Since the crisis in 2008, the dynamics of the Chinese and American economies have changed. In Charts 3 and 4, we verify the evolution of the macroeconomic variables used in this article. The structural break that we saw in the evolution of the variables may affect the non-rejection of the unit root tests. Chart 3 shows the evolution of the variables BBE, BBC, CE and EE. Chart 4 shows the evolution of the variables BC, YC, YE and SG.

Looking at the evolution of the variables, we can see that all the variables could have a structural break. This breakdown occurred in most cases in the period between 2007 and 2009, the period that marked the beginning and the epicenter of the subprime crisis. Moreover, another indicator in favor of the presence of a structural break series is demonstrated in Table 4.

The most important descriptive statistic of Table 4 is the coefficient of variation. This coefficient shows the dispersion of the observations concerning the mean. The higher the coefficient, the greater the dispersion. As we can see, in three variables (BBC, SG and YE), the coefficient of variation is larger than 80%. In only two cases (EC and EE), this coefficient is smaller than 10%.

[1] More information about these tests can be found in Bueno (2008) and Enders (2010).

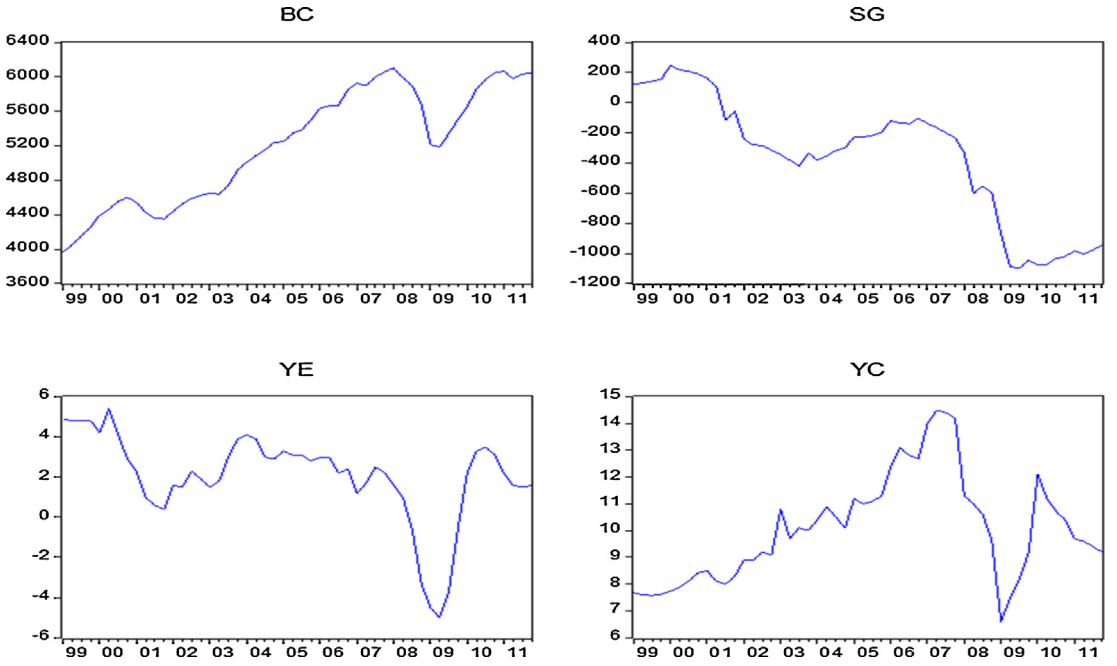

Chart 4. Evolution of the variables BC, YE, YC and SG in the period 1999–2011.
Chart prepared by the authors using data from the article.

Table 4
Some descriptive statistics of the variables used in the model.

	BBC	BBE	BC	EC	EE	SG	YC	YE
Mean	7.65	−42.67	5202.19	100.47	109.75	−362.12	10.06	2.04
Maximum	23.95	−23.13	6102.02	116.10	126.60	247.49	14.50	5.40
Minimum	−2.14	−59.37	3970.27	85.40	97.00	−1097.7	6.60	−5.00
Standard deviation	6.41	10.13	664.69	8.59	7.63	416.10	1.97	2.23
Coefficient of variation	84%	−24%	13%	9%	7%	−115%	20%	109%

Source: Table prepared by the authors using data from the article.

Despite these signs of structural breaks presented in Chart 3, Chart 4 and Table 4, we ran unit root test for variables with structural breaks, because according to Perron (1989), these kinds of variables may lead to incorrect inferences about the order of integration.

There are two different types of unit root tests with structural breaks. For Lee and Strazicih (2004), in the first group are tests that assume that the break point was known a priori, like Perron (1989). In the words of Paine et al. (2005), "imposing pre-determined breaks might induce incorrectly specified break points."

In the second group are tests in which the point break is found endogenously, like Zivot and Andrews (1992). The results of the Zivot and Andrews test are shown in Table 5.

As we can see in Table 5, only three variables (BBE, YC and BC) are stationary at the 5% level of significance. According to Paine et al. (2005), in many applications of this test, the null hypothesis test is often rejected. Rejection of the null, however, does not necessarily imply rejection of the unit root per se, but in many cases rejection of the unit root without a break. This causes size distortions, leading to frequent spurious rejections.

Concerning this problem, Lee and Strazicih (2003, 2004) offered unit root tests that are free of size distortion and free of spurious rejection in the presence of a unit root with structural break. The tests of Lee and Strazivich also tend

Table 5
Zivot and Andrews unit root test with a structural break.

Variable	Type	Lags	Coefficient	Moment of break
BBE	Intercept	1	−6.37***	2008.04
BBC	Intercept	0	−3.41	–
YE	Intercept	1	4.13	–
YC	Intercept	0	−4.83**	2008.01
BC	Intercept + Trend	1	−4.99**	2008.04
EE	Intercept	2	−3.05	–
EC	Intercept	2	−3.05	–
SG	Intercept	0	2.93	–

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

Table 6
Unit root test with a structural break.

Variable	Type	One break			Two breaks		
		Lags	*t-statistic*	Moment of break	Lags	*t-statistic*	Moment of break
BBE	Break	3	−4.211	2008.02	3	−5.169	2008.02 e 2010.03
BBC	Break	1	−4.200*	2006.03	1	−6.090**	2003.04 e 2008.01
YE	Break	2	−4.095	–	2	−5.194	2003.01 e 2009.03
YC	Break	0	−2.847	2007.04	2	−5.759**	2006.03 e 2008.04
BC	Crash	4	−3.361*	2008.04	2	−3.703*	2008.04
EE	Crash	1	−1.862	–	1	−1.990	–
EC	Crash	1	−2.590	–	2	−2.825	–
SG	Break	4	−3.882	2007.04	4	−4.692	2004.03 e 2008.03

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

to estimate the break point correctly and are invariant to the magnitude of a break and its location.[2] The results are reported in Table 6.

As shown in Table 6, the test rejected the null hypothesis of the presence of a unit root only for the variables BC and BBC, in the case of one break, at the 10% level of significance. In the unit root test with two breaks, the test rejected the null hypothesis of a unit root with a structural break for the variables BBC and YC at the 5% level of significance and the variable BC at the 10% level of significance. Many of the structural breaks detected were significant and associated with the year 2008. This was the year of the outbreak of the subprime crisis.

The structural breaks are seemingly not problems, although there are significant breaks in the majority of the variables. The only two variables for which the test did not detect breaks are EC and EE. Looking backward, we can see in Table 4 that these two variables suffered less distortion than any of the others in the period of analysis of this work.

Therefore, we executed traditional unit root tests (ADF, DF-GLS, Philips–Perron, KPSS, ERS, Ng–Perron) in first differences. The results of the tests are presented in Tables 7–12.

Examining Tables 7–11, we can conclude that almost all the variables are I(1) at the 5% level of significance in the ADF, DF-GLS, Philips–Perron, KPSS and ERS tests. The exceptions are the variable EE in the ADF and ERS test and the variable SG in DF-GLS. However, as we have already indicated, the Ng–Perron test has gains of power and size. Because of those gains, we chose the Ng–Perron test to select the variables of the model of this paper. In the Ng–Perron test, except for SG, all the variables are I(1) at the 5% level of significance.

[2] According to Saikkonen and Lutkepohl (2002), the literature on unit root tests with an unknown structural break can be found in article like Zivot and Andrews (1992).

Table 7a
ERS test with variables in the first difference.

Variable	Type	Lags	Coefficient
BBE	Intercept	3	0.11***
BBC	Intercept	1	0.72***
YE	Intercept	3	0.01***
YC	Intercept	0	0.95***
BC	Intercept + Trend	0	5.04**
EE	Intercept	4	3.78*
EC	Intercept	2	0.70***
SG	Intercept	0	1.07***

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

Table 7b
Granger causality test following the Toda–Yamamoto approach.

Model	Granger causality test	Chi-squared statistic of Wald test	BIC	AIC
First VAR	Unilateral Causality	8.529***	9.96	9.42
	BBC←BBe BBC→BBE	1.924		
Second VAR	Unilateral Causality	10.754***	9.90	9.20
	BBC←BBE BBC→BBE	1.232		
Third VAR	Simultaneity	7.345***	9.71	8.94
	BBC←BBE BBC→BBE	3.785**		
Fourth VAR	Simultaneity	4.793**	9.90	8.91
	BBC←BBE BBC→BBE	3.335*		
Fifth VAR	Unilateral Causality	0.927	10.01	8.94
	BBC←BBE BBC→BBE	3.533*		

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

Table 8a
KPSS test with variables in the first difference.

Variable	Type	Lags	Coefficient
BBE	Intercept	2	0.18***
BBC	Intercept	14	0.17***
YE	Intercept	2	0.05***
YC	Intercept	1	0.13***
BC	Intercept + Trend	3	0.04***
EE	Intercept	1	0.30***
EC	Intercept	2	0.11***
SG	Intercept	4	0.08***

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

Table 8b
Cointegration test for the variables BBC and BBE.

Variables	*T*-Statistic	*Lags* (SIC)	Type
BBC Residual	−1.943	0	Intercept + Trend
BBE Residual	−4.614**	3	Intercept

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

Table 9a
Philips–Perron test with variables in the first difference.

Variable	Type	Lags	Coefficient
BBE	Intercept	2	-4.40^{***}
BBC	Intercept	17	-5.90^{***}
YE	Intercept	1	-3.83^{***}
YC	Intercept	0	-6.40^{***}
BC	Intercept + Trend	0	-3.69^{**}
EE	Intercept	3	-4.27^{***}
EC	Intercept	5	-4.37^{***}
SG	Intercept	3	-5.80^{***}

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

Table 9b
Weak exogeneity test for *BBE*.

Variable	Coefficient	Std Error	*T*-Statistic	*P*-Value
Constant	−0.172	0.502	−0.342	0.733
Π_2	0.654	0.180	3.624	0.0007***

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% e 10%, respectively.

Table 10a
ADF test with variables in the first difference.

Variable	Type	Lags	Information criterion	Coefficient
BBE	Intercept	1	AIC	-4.06^{***}
BBC	Intercept	1	AIC	-5.74^{***}
YE	Intercept	3	AIC	-4.88^{***}
YC	Intercept	0	AIC	-6.40^{***}
BC	Intercept + Trend	0	AIC	-3.69^{**}
EE	Intercept	4	AIC	−2.10
EC	Intercept	1	AIC	-5.24^{***}
SG	Intercept	2	AIC	-5.74^{***}

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

5.2. *Granger causality test following the Toda–Yamamoto method*

Starting with Eqs. (4) and (5), which presented the variables used in the current work, several models were estimated. The first model, a bivariate VAR, was specified only with the variables BBC and BBE. In the second model, a trivariate VAR, we added the exchange rates of the U.S. and China, because of the effect that they have on the current account balance, as explained in the methodology.

In the third model, a multivariate VAR, we included the variable BC, which represents the level of world trade. In the fourth VAR, we added YC and YE to indicate the level of activity of the domestic product of the countries and the relationship they have with the current account balance. Finally, in the fifth VAR, we included SG, since it is expected that the U.S. public deficit has an effect on the macroeconomic imbalance, as has already been explained in the methodology.

We chose the third VAR as the best model, according to the information criteria BIC and AIC. This model was also chosen because it did not provide serial autocorrelation of the residuals. The choice of lag was two, according to four information criteria (LR, FPE, AIC and HQ); only one of the criteria (SIC) pointed to one lag. Since we used the Toda–Yamamoto methodology, a new lag was added to the model, since this is the order of integration of the variables. In the end, we used a lag of three for the VAR. Table 7 provides the statistics of the models that we tested in the

Table 10b
Weak exogeneity test for *DBBE*.

Variable	Coefficient	Std Error	*T*-Statistic	*P*-Value
Constant	−0.111	0.515	−0.215	0.830
Π_4	0.163	0.185	0.884	0.380

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

Table 11a
DF-GLS test with variables in the first difference.

Variable	Type	Lags	Information criterion	Coefficient
BBE	Intercept	0	MAIC	-3.95^{***}
BBC	Intercept	0	MAIC	-5.91^{***}
YE	Intercept	0	MAIC	-3.81^{***}
YC	Intercept	1	MAIC	-4.49^{***}
BC	Intercept + Trend	0	MAIC	-3.76^{**}
EE	Intercept	4	MAIC	-2.10^{**}
EC	Intercept	4	MAIC	-2.19^{**}
SG	Intercept	3	MAIC	-1.91^{*}

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

work and the Granger causality test following the Toda–Yamamoto approach. Eqs. (6) and (7) provide the conditional models used in the exercise.

$$BBC = \beta_0 + \beta_1 BBE + \beta_2 EC + \beta_3 EE + \beta_4 BC + \theta \tag{6}$$

$$BBE = \beta_0 + \beta_1 BBC + \beta_2 EC + \beta_3 EE + \beta_4 BC + \mu \tag{7}$$

We can see in Table 7, using the methodology of Toda–Yamamoto, the causality tests in the Granger sense for all the models. In the first and second VARs, the result was that BBE causes BBC in the Granger sense, at the 1% level of significance. The fifth VAR is the opposite; BBC causes BBE in the Granger sense, at the 10% level of significance. However, the third and fourth VARs showed simultaneity, at the 1% level of significance in the first case and the 10% level in the second.

5.3. Weak exogeneity test

According to Sachsida (1999), before running exogeneity tests, it is necessary to perform the Engle–Granger cointegration shown in Eqs. (6) and (7) (which represents the conditional model), since not all the variables used in the article are I(1). According to Sachsida (1999), the analysis of exogeneity, when the variables of the regression are (1), can be spurious when we use the variables in levels. On the other hand, when the residuals of the regressions are I(0), they characterize a long-term relationship between the variables. Table 8 shows the results of the augmented Engle–Granger tests from Eqs. (6) and (7).

We can see from Table 8 that we cannot reject the null hypothesis of a unit root for the residuals BBC conditional model. This means that the variables do not cointegrate. In relation to the conditional model of BBE, it is possible to reject the null hypothesis at the 5% level of significance; the conditional model BBE does cointegrate. With the results of the cointegration tests, we executed exogeneity tests. Initially, we tested the weak exogeneity for the conditional model-level BBC. The test is represented by Eqs. (6), (8) and (9), and the results thereof in Table 9.

$$BBE = \alpha_1 + \alpha_2 BBE(-1) + \alpha_3 BBE(-2) + \alpha_4 BBE(-3) + \in \tag{8}$$

$$\theta = \prod_1 + \prod_2 \hat{\varepsilon} + \tau \tag{9}$$

Table 11b
Weak exogeneity test for *BBC*.

Variable	Coefficient	Std Error	*T*-Statistic	*P*-Value
Constant	0.0625	0.424	0.147	0.883
ρ_2	−0.262	0.177	−1.479	0.145

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

Table 12a
Ng–Perron test with variables in the first difference.

Variable	Type	Lags	MZA	MZT	MSB	MPT
BBE	Intercept	0	-17.09^{***}	-2.92^{***}	0.17^{***}	1.43^{***}
BBC	Intercept	0	-23.82^{***}	-3.35^{***}	0.14^{***}	1.33^{***}
YE	Intercept	0	-23.82^{***}	-3.35^{***}	0.14^{***}	1.33^{***}
YC	Intercept	0	-23.92^{***}	-3.45^{***}	0.14^{***}	1.02^{***}
BC	Intercept + Trend	0	-17.38^{**}	-2.94^{**}	0.16^{*}	5.24^{**}
EE	Intercept	0	-20.17^{***}	-3.07^{***}	0.15^{***}	1.56^{***}
EC	Intercept	0	-19.81^{***}	-3.09^{***}	0.15^{***}	1.42^{***}
SG	Intercept	3	−5.18	−1.59	0.30	4.77

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

The models used in the test did not show serial auto-correlation in the residuals. The adjusted R^2 was 0.60 in the case of Eq. (6) and 0.80 in Eq. (8). According to Table 9, the residuals of the BBE marginal model (Eq. (8)) are significant at the 1% level when regressed against the residues of the BBC conditional model (Eq. (6)). This fact prevents the BBE variable from being weakly exogenous with respect to the BBC conditional model. However, since cointegration was not detected in the BBC conditional model, we ran a new test of weak exogeneity with the BBC conditional model in the first differences. Eqs. (10)–(12) represent the operation while Table 10 presents the results. We did not detect serial auto-correlation in the residuals of Eq. (10), and we detected an increase in the adjusted R^2 to 0.66.

$$DBBC = \beta_0 + \beta_1 DBBE + \beta_2 DEC + \beta_3 DEE + \beta_4 DBC + \theta \tag{10}$$

$$BBE = \alpha_1 + \alpha_2 BBE(-1) + \alpha_3 BBE(-2) + \alpha_4 BBE(-3) + \in \tag{11}$$

$$\hat{\theta} = \prod_3 + \prod_4 \hat{\in} + \tau \tag{12}$$

Looking at Table 10, we can see that estimated residual of the marginal model (Eq. (11)) was not different from zero at the 5% level of significance when regressed against the residuals of the conditional model (Eq. (10)). This means that BBE is weakly exogenous with respect to BBC, adopting the conditional model in first differences. This result shows that the model of Eq. (10) is a good model to use for inference, since it does not suffer from endogeneity bias with respect to the variable BBE. The exogeneity test for the variable BBC and the same result can be checked in Eqs. (7), (13) and (14) and Table 11, respectively. With respect to the BBC marginal model, it has been modified, since it showed serial auto-correlation of the residuals. The solution was to add the variable EE with a lag. The model of Eq. (7) showed an adjusted R^2 of 0.90 and Eq. (13) showed an adjusted-R^2 of 0.83.

$$BBC = \alpha_1 + \alpha_2 BBC(-1) + \alpha_3 BBC(-2) + \alpha_4 BBC(-3) + \beta_5 EE(-1) + \sigma \tag{13}$$

$$\hat{\varepsilon} = \rho_1 + \rho_2 \hat{\sigma} + \tau \tag{14}$$

According to Table 11, BBC is weakly exogenous with respect to the BBE conditional model (Eq. (7)). This means that the marginal model (Eq. (13)) does not provide additional information to the conditional model, since it cannot be said that the marginal residuals of the model are different from zero at the 5% level of significance. It was not necessary to run this test of the BBE conditional model in first differences, since the model in levels does cointegrate.

Table 12b
Granger causality test.

LAGS	Null hypothesis	Coefficient Wald Test	*P*-Value
3	BBC does not cause BBE in Granger sense	3.785	0.0517**
	BBE does not cause BBC in Granger sense	7.345	0.0067***

Source: Table prepared by the authors using data from the article.
***, **, * Significance level of 1%, 5% and 10%, respectively.

Table 13
Superexogeneity test for *BBE*.

Type	Value	*P*-Value
F-Statistic	18.445	0.0001
Chi-Squared Statistic	18.445	0.0000

Source: Table prepared by the authors using data from the article.

5.4. Strong exogeneity test

As we already been mentioned in the methodology, the requirements for a variable to be considered strongly exogenous in a model are weak exogeneity and no causality in the Granger sense. Table 12 shows the results of the Granger causality test obtained by the Toda–Yamamoto method.

The Granger causality test shown in Table 12 pointed to simultaneity, since the sum of the lags of the variable BBC are different from zero when the variable is regressed against the BBE model at the 5% level of significance. The same occurred with the sum of the lags of the variable BBE; they are also different from zero when regressed against BBC at the 1% level of significance. The conclusion drawn is that the variables are not strongly exogenous, even though the first requirement has been established (the weak exogeneity of both variables). When there is simultaneity, according to Sachsida (1999), there is no strong exogeneity. The simultaneity means that the external balance of China has preceded and has been preceded temporally by the U.S. external balance, or causes and was caused in the Granger sense by the U.S. external balance.

5.5. Superexogeneity test

This test uses the square of the residuals of the marginal equation and its lags as an independent variable in the conditional equation. If these independent variables are statistically different from zero, we can say that there is no superexogeneity. When we were formulating the marginal model, we added a dummy (DM) for the subprime crisis, as in Kurita (2007). This dummy covers the whole year 2008, since the LM unit root tests pointed to a structural break in this period. The equations and their test results for the variable BBE can be seen in Eqs. (15) and (16) and Table 13, respectively.

$$BBE = \alpha_1 + \alpha_2 BBE(-1) + \alpha_3 BBE(-2) + \alpha_4 BBE(-3) + \alpha_5 DM + \in \tag{15}$$

$$BBC = \beta_0 + \beta_1 BBE + \beta_2 EC + \beta_3 EE + \beta_4 BC + \hat{\in}^2 + \hat{\in}(-1)^2 + \prod \tag{16}$$

We can observe that the Wald test for the squared residuals of the BBE marginal equation (Eq. (15)) rejects the null hypothesis that they together (with their lags) are equal to zero. However, since the BBC conditional model did not cointegrate, we used the BBC conditional model in first differences to conduct a new test. Eq. (17) represents the test and Table 14 the results.

$$DBBC = \beta_0 + \beta_1 DBBE + \beta_2 DEC + \beta_3 DEE + \beta_4 DBC + \hat{\in}^2 + \hat{\in}(-1)^2 + \prod \tag{17}$$

Table 14 shows that BBE is a superexogenous variable with respect to the BBC, since the Wald test rejects that the sum of the squared residuals (with its lags) of the marginal model at the 5% level of significance is equal to zero. The

Table 14
Superexogeneity test for BBE with the conditional model in first differences.

Type	Value	*P*-Value
F-Statistic	10.410	0.002
Chi-Squared Statistic	10.410	0.001

Source: Table prepared by the authors using data from the article.

Table 15
Superexogeneity test for *BBC*.

Type	Value	*P*-Value
F-Statistic	0.066	0.936
Chi-Squared Statistic	0.066	0.935

Source: Table prepared by the authors using data from the article.

Type	**BBE**	**BBC**
Weak Exogeneity	YES	YES
Strong Exogeneity	NO	NO
Superexogeneity	NO	YES

Chart 5. Exogeneity results.
Source: Chart prepared by the authors using data from the article.

variable BBE is not a superexogenous variable regarding the BBC conditional model. The equation and the results for the variable BBC can be seen in Eqs. (18) and (19) and Table 15.

$$BBC = \alpha_1 + \alpha_2 BBC(-1) + \alpha_3 BBC(-2) + \alpha_4 BBC(-3) + \beta_5 EE(-1) + DM + \sigma \tag{18}$$

$$BBE = \beta_0 + \beta_1 BBC + \beta_2 EC + \beta_3 EE + \beta_4 BC + \hat{\sigma}^2 + \hat{\sigma}(-1)^2 + \rho \tag{19}$$

As can be seen from Table 15, BBC is a superexogenous variable with respect to BBE since the Wald test does not reject the residuals and the gaps of the marginal model are different from zero. Another conclusion that can be drawn from the tests is that the crisis dummy is significant in the BBE marginal model, with strong evidence of the instability of these parameters. Since BBC is a supereoxogenous variable in the BBE model, this means that the model can be used in the formulation of public policy, since there is invariance in the structural model. In other words, the dynamics of the BBE model before the crisis remained after the crisis; even a crisis dummy in the model of marginal BBC is not significant at the level of 5%.

5.6. Summary and economic interpretation of the econometric results

The econometric tests used in this article showed that there is a link between the U.S. and the Chinese external balance. As can be seen in Chart 5, despite the weak exogeneity having been satisfied, strong exogeneity was not found in any case and superexogeneity only once. The non-occurrence of strong exogeneity means that a causal relationship existed between the U.S. external balance and the Chinese external balance. In the test of superexogeneity, the detection even in the conditional model BBE showed that there was a change in the dynamic behavior of the conditional model of the U.S. external balance after the crisis and that there was not this same change with respect to the conditional model of the external balance Chinese.

These superexogneity test results were expected, since, as can be seen in Table 1, the average of the U.S. current account balance two years before the peak of the crisis in 2008 decreased from U.S. $755 billion to an average of $423 billion in the two years after the peak of the crisis, a drop of almost 40%, which shows that there was a strong shift in the dynamics of the current account balance in the U.S. Regarding the Chinese current account balance, still according to Table 1, the current account surplus decreased from an average of $293 billion in the two years preceding

the crisis to an average of U.S. $283 billion two years after the crisis, demonstrating that there was a decrease of only 4%, so we did not detect superexogeneity in the BBC conditional model. Failure to change the dynamics of the Chinese current account surplus after the crisis of 2008, which grew steadily from 2001 to 2008, can also be endorsed by the participation of the same current account deficit in the U.S., which moved from a 40% average in both years before the crisis to a 67% average in the two years that included the crisis.

6. Conclusion

After performing all the econometric exercises proposed in the methodology, there is evidence that the macroeconomic imbalances between the U.S. and China were actually interconnected, reinforcing the hypothesis that there is an influence on the dynamics of the 2008 crisis. The data presented in the introduction and context suggest an inverse relationship between the current account balance of the U.S. and that of China. This relationship is explored initially in the correlation matrix contained in Table 3.

Regarding strong exogeneity, the prerequisite of weak exogeneity had already been proven. However, the prerequisite for non-causality in the Granger sense was not satisfied, since the result found was simultaneity, so this provides more proof of the existence of a temporal relationship between the U.S. external deficit and the Chinese external surplus. Superexogeneity was detected only for the variable of the balance of goods from China (BBC) with respect to the conditional model of the balance of U.S. goods (BBE). This fact indicates the robustness of the model to a change in economic policy. It is interesting to note that the relationship between BBC and BBE, shown by the conditional model, demonstrated that the BBE conditional equation remained unchanged even after the crisis.

On the other hand, the variable BBE is not a supereoxogenous variable with respect to the BBC conditional model, and we could argue that the dynamics of the BBC conditional model changed after the subprime crisis since instability was detected in the marginal models from the 2008 crisis. The tests point unequivocally to the existence of endogeneity between the U.S. balance of goods (BBE) and the net assets of China (BBC). The data analyzed in the motivation section showed that the imbalances were increasing in the pre-subprime crisis era and experienced a strong adjustment thereafter. In addition, the unit root tests detected structural breaks in BBE and BBC in 2008, supporting the literature suggesting that the large increase in the macroeconomic imbalance between the U.S. and China has a relationship with the subprime crisis.

References

Aizenman, J., Jinjarak, Y., NBER Working Paper 2009. The US as the Demander of Last Resort and its Implications on China's Current Account.

Araujo, E.C., Dias, J., 2006. Endogeneidade do Setor Financeiro e crescimento econômico: Uma análise empírica para a economia brasileira (1980–2003). Revista de Economia Contemporânea 10, 575–610.

Bresser-Pereira, L.C., 2009. A crise Financeira de 2008: a crise e recuperação da confiança. Revista de Economia Política 29, 133–149.

Bueno, R.D.L.S., 2008. Econometria de Séries Temporais, 1st ed. Cengage Learning, São Paulo.

Caballero, R.J., NBER Working Paper 2010. Other Global Imbalances.

Caballero, R.J., Krishnamurthy, A., NBER Working Paper 2009. Global Imbalances and Financial Fragility.

Cardim, F.C., Brazilian Keynesian Association Working Papers 2008. Understanding the Recent Global Financial Crisis.

Catte, P., Cova, P., Pagano, P., Visco, I., 2011. The role of macroeconomic policies in the global crisis. J. Policy Model. 33, 787–803.

Cheung, Y.W., Chinn, M.D., Fujii, E., NBER Working Paper 2009. China's Current Account and Exchange Rate.

Chinn, M.D., Eichengreen, B., Ito, H., NBER Working Paper 2011. A Forensic Analysis of Global Imbalances.

Corden, W.M., 2009. China's exchange rate policy, its current account surplus and the global imbalances. Econ. J. Malden 119, 430–441.

Divino, J.A., Teles, W.K., Andrade, J.P., 2009. On the purchasing power parity for Latin-American countries. J. Appl. Econ. 12, 33–54.

Enders, W., 2010. Applied Econometric Time Series, 2nd ed. Leyh Publishing LLC, Alabama.

Engle, R.F., Hendry, D.F., Richard, J., 1983. Exogeneity. Econometrica 51, 277–304.

Feldstein, M.S., NBER Working Paper 2011. The Role of Currency Realignments in Eliminating the US and China Current Account Imbalances.

Granger, C.W.J., 1969. Investigating casual relations by econometric models and cross-spectral methods. Econometrica 37, 424–438.

Hallett, A.H., Oliva, J.C.M., 2011. Reducing global imbalances: can fixed exchange rates and current account limits help? Open Econ. Rev. 23, 163–192.

Hendry, D., 1995. Dynamic Econometrics: Advanced Texts in Econometrics, 1st ed. Oxford University Press, United Kingdom.

Kurita, T., 2007. A dynamic econometric system for the real yen–dollar rate. Empirical Econ. 33, 115–149.

Lane, P.R., Milesi-Ferreti, G.M., 2011. External adjustment and the global crisis. J. Int. Econ. 88, 252–256.

Lee, J., Strazicih, M.C., 2003. Minimum Lagrange multiplier unit root test with two structural breaks. Rev. Econ. Stat. 85, 1082–1089.

Lee, J., Strazicih, M.C., Working Paper 2004. Minimum LM Unit Root Test With One Structural Break.

Mackinnon, R., Schnabl, G., BIS Working Papers 2009. China's Financial Conundrum and Global Imbalances.

Ng, S., Perron, P., 2001. Lag length selection and the construction of unit root tests with good size and power. Econometrica 69, 1519–1554.
Paine, J., Lee, J., Hofler, R., 2005. Purchasing power parity: evidence from a transition economy. J. Econ. Model. 27, 665–672.
Paula, L.F., Ferrari, F.F., Brazilian Keynesian Association Working Papers 2010. Keynesian Time.
Perron, P., 1989. The great crash, the oil price, and the null hypothesis. Econometrica 57, 1361–1401.
Perron, P., Qu, Z., 2007. A simple modification to improve the finity sample properties of Ng and Perron's unit root tests. Econ. Lett. 94, 12–19.
Reinhart, M.R., Rogoff, K.S., 2009. This Time is Different: Eight Centuries of Financial Folly, 1st ed. Princeton University Press, United States.
Resende, L.A., Casa das Garças Institute Working Papers 2009. After the Crisis: Macro Imbalance, Credibility and Currency Reserve.
Sachsida, A., Ipea Working Papers 1999. Exogeneity Test on the Correlation between Domestic Savings and Investment.
Sachsida, A., Mendonça, M.J.C., Ipea Working Papers 2006. Domestic Saving and Investment Revised: Can the Feldstein–Horioka Equation Be Used for Policy Analysis?
Saikkonen, P., Lutkepohl, H., 2002. Testing for unit root in a time series with a level shift at unknown time. Ecoomet. Theor. 18, 313–348.
Toda, H.Y., Yamamoto, T., 1995. Statistical inference in vector autoregressions with possibly integrated processes. J. Econ. 66, 225–250.
Tomazzia, E.C., Meurer, R., 2009. O mecanismo de transmissão da política monetária no Brasil: Uma análise em VAR por setor industrial. Economia Aplicada 13, 371–398.
Zapata, H.O., Rambaldi, A.N., 1997. Monte Carlo evidence on cointegration and causation. Oxf. Bull. Econ. Stat. 59, 285–298.
Zivot, E., Andrews, D.W.K., 1992. Further evidence on the great crash, the oil-price shock and the unit-root hypothesis. J. Bus. Econ. Stat. 10, 25–44.